From The Ground Up

Exploring the role of horticultural data in locally-grown food systems

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Image: Liz Christy's Bowery-Houston Garden, named in honor of environmental activist and co-founder Green Guerilla Liz Christy, via Openverse, taken by gsc

Table of Contents

Synopsis

Current food production and distribution systems are ecologically and environmentally unsustainable and will continue to exacerbate food equity issues for the most vulnerable populations. Research supports that civic farming investments, including urban farming, community gardens, and farmer's markets, support local communities culturally and nutritionally, but rarely addresses the potential impact of home growing initiatives. While home growing initiatives present difficulties in scaling, they have a notable history of supporting NYC communities through times of crisis. To replicate the impact of successful hyper-local food systems in the past, modern data practices and easy-to-use design systems need to be implemented to fill the gaps in institutional investment.

From the Ground Up explores the current landscape of plant data presently available to potential growers with the aim of fostering participation, curiosity, and confidence in applying plant data. The project explores data aggregated from Plants for a Future, the United States Department of Agriculture, The Farmer's Almanac, and the National Gardening Association to invite users to identify plant cultivation needs and practical uses that fit their needs. The visualizations focus on representing use cases most relevant to urban farming in New York City, prioritizing data for plants that grow successfully in temperate climate zones. Users can filter data for more than 5,000 plants based on plant needs, plant tolerances, and aggregated uses. The visualizations further connect to other online resources and provide information to enable users' self-education and encourage in-person connection and continued participation in sustainable food growing practices in their communities and at home. *From the Ground Up* aims to make plant research exciting and accessible to larger communities and to implement modern data practices within collective horticultural knowledge.

Introduction

New Yorkers consume an average of 18 pounds of fresh tomatoes each, per year, and more than 95% of those tomatoes are shipped more than 2,000 miles before they find their way to our kitchens[1]. If each of the 8.4 million residents of New York City grew one tomato plant, which can produce up to 20lbs per plant within 2 square feet, we could drastically reduce the carbon footprint of that 151.5 million pounds of tomatoes. Whether it be in the 4.3 million sq. ft. in NYC's community gardens[2], on the potential 316 million sq. ft. of suitable green rooftop area[3], or in DIY container gardens found on front stoops, fire escapes, and backyards, the potential to reshape the impact and risk of our food consumption is huge - and it might start at home.

While no one should expect every person to grow all their own food, the implications of local food production could be significant at any scale. Our relationship to food has shifted greatly over the last 100 years, and we currently rely on many complicated production systems in order to meet basic nutritional needs, increase variety in our diets, and keep food costs down. While changes in population, transportation, labor, and technology have driven food production away from "kitchen gardens", those same problems may bring us back to local food production methods today.

Current food production and distribution systems are unsustainable on both economic and ecological levels as agricultural production is predicted to fall short of demand within the next several decades, environmental consequences of intensified agricultural systems notwithstanding[4].

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[1] Institute, "Building the Case for Controlled Environment Agriculture (CEA) in New York State."
[2] NYC Parks, "Green Guerrillas Gain Ground."
[3] Serr, "Exploring Green Roof Potential In NYC."
[4] Vira and Mansourian (eds), *Forests and Food*.

From an economic perspective: food prices can vary greatly from the interaction of exponentially complicated variables such as weather, transportation, labor and production costs, and political factors in global trade. During the Covid-19 pandemic, access to food plummeted with the number of people experiencing food insecurity jumping by 36% in NYC[5] - due in part to a dramatic decrease in household incomes and in part to increased transportation and storage costs while systems remained unpredictably disrupted. Climate change has also begun to affect food prices, with global food costs rising by 31% between 2020-2021[6] and staple crops such as maize, soy and wheat projected to ride further in the future, as reported by the IPCC[7]. Recent trade sanctions with Russia are projected to affect costs of wheat, corn, vegetable oil due to increases in fertilizer and transportation costs[8]. Considering that food makes up a 27% of spending lower income households while only making up 7% of spending in higher income households[9], any volatility in food access in the global food market risks disproportionately affecting food access for lower-income households and can have damaging ramifications for nutrition, healthcare, and education in these communities. Localized systems can provide some amount of stability in the predictability of food production and transportation costs[10]. While food availability and prices can fluctuate in smaller systems such as farmer's markets[11], research consistently shows that engaging in locally-grown food systems strengthens economic and ecological systems in communities[12].

Charles Platkin, Ph.D., J.D., M.P.H., and the Executive Director, Hunter College New York City Food Policy Center notes in his testimony for the hearing "The State of Community Gardens and Urban Agriculture and Intro No. 1059 A Local Law in relation to a report on community garden food processing and agriculture.":

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5 Stephens, "Hunger in NYC."
6 Bauza, "Climate-Driven Crop Failures Are Driving up Food Prices: 3 Stories You May Have Missed."
7 Dasgupta et al., "Chapter 9."
8 Fraser, "The Effect of War on Food Prices."
9 Martin, "USDA ERS - Food Prices and Spending."
10 Mbow and Rosenzweig, "Chapter 5."
11 Claro, "Vermont Farmers' Markets and Grocery Stores: A Price Comparison."
12 Schmit, Jablonski, and Mansury, "Assessing the Economic Impacts of Local Food System Producers by Scale."

> "A growing body of research suggests that urban agriculture, including community gardens harvest nutritionally and economically meaningful amounts of nutritious food, which is especially valuable in areas where access to fresh fruits and vegetables are limited."[13]

Current urban agriculture initiatives broadly include private and publicly funded urban farms, community gardens, community supported agriculture (CSAs), and farmers' markets[14]. These initiatives can also be described as "civic agriculture", defined by Thomas A. Dyson (2012) as "the embedding of local agricultural and food production in the community." Dyson further explains that there are social and financial benefits to communities when food systems are more localized in his book "Civic Agriculture: Reconnecting Farm, Food, and Community" (2012):

> "Civic agriculture is not only a source of family income for the farmer and food processor; civic agricultural enterprises contribute to the health and vitality of communities in a variety of social, economic, political, and cultural ways. For example, civic agriculture increases agricultural literacy by directly linking consumers to producers. Likewise, civic agricultural enterprises have a much higher local economic multiplier than farms or processors that are producing for the global mass market. Dollars spent for locally produced food and agricultural products circulate several times more through the local community than money spent for products manufactured by multinational corporations"[15]

The ongoing research that economies, education, and nutritional equity are strengthened by localized food systems and can help limit fluctuations in access to fresh food subject to political and climate change-related concerns has built a case for many governments and third sector groups to increase resources in these systems at regional levels.

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[13] Platkin et al., "Testimony on the Importance of Community Gardens."
[14] "Agricultural Law Information Partnership: Urban Agriculture."
[15] Lyson, *Civic Agriculture*.

Empowering communities to build sustainable and equitable food systems involves significant investment in farmer's markets, urban agriculture, community and home gardens. While there are substantial food policy initiatives throughout New York City such as United States Department of Agriculture (USDA) grants enabling the use of food stamps at farmers' markets[16], expansion of Greenthumb community garden programming and funding[17], and the creation of a new Office of Urban Agriculture and Innovative Production within the 2018 Farm Bill[18], present assessments of the potential impact of urban agriculture regularly forsake incorporating any amount of home growing in part due to the inability to measure this impact with any predictability. Additionally, community and home gardening initiatives still rely on larger interconnected systems for the distribution of resources and educational materials and these resources remain largely hands-on and in-person, which limits accessibility. The present learning curve for individuals to start growing their own food is too steep for mass adoption, as engagement with existing information sources remains opaque, bureaucratic, and unintuitive - leaving potential growers to start from scratch when they do find resources for growing.

There is an opportunity in horticultural education and food policy to explore data sets managed by online communities as well as by professional agencies. There is a huge amount of highly detailed information available to beginner gardeners both on- and off-line discussing the many variables in growing food and other plants and the complexities created by the interaction of these variables. There is further variation in the quality of the data available as these information sources can range greatly in depth, structure, clarity. The complexities in a prospective gardener's specific situation result in the need for hybrid education solutions that encourage people to both research on their own and learn from garden communities in real life. This thesis aims to explore horticultural data in a way that makes users feel curious and confident to engage with local communities.

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[16] Gallahue and Merlino, "Good Health, Good Value: NYC Receives $5.5 Million Grant to Make Healthy Food More Affordable."

[17] NYS Division of Budget, "Agency Appropriations Budget Highlights."

[18] Reynolds, "Perspectives on Int. No. 1058-2018: A Local Law in Relation to Developing a Comprehensive Urban Agriculture Plan."

The data explored in this research examines patterns in hardiness, physical qualities, cultivation and applications in temperate climate plants found primarily in datasets maintained by Plants for a Future[19], The National Gardening Association[20], and the United States Department of Agriculture[21]. The data includes rich cultivation details such as light, water, drainage, chemical and climate tolerances, and edible, medicinal and material uses across more than 7,000 plants selected for their ability to grow in a temperate climate, as Plants for a Future is UK-based. By constructing a focused user experience and modern interface, this thesis aims to make a vast amount of complex data more actionable in helping curious community and home gardeners scale their own food production.

[19] Fern, "Plants for a Future." https://pfaf.org/user/Default.aspx
[20] National Gardening Association, "Plant Databases." https://garden.org/plants
[21] "USDA Plants Database." https://plants.sc.egov.usda.gov/home

Background

Terminology

In this project, the terms “**gardening**”, “**agriculture**”**,** and “**horticulture**” are used in the context of non-industrialized food growing practices. While gardening can be used to describe the practice of growing edible and non-edible plants alike, here “gardening” is used in alignment with the mission of the National Gardening Association:

> “From vegetables, herbs, fruits, trees, lawns, flowers, and houseplants, we provide people with the information they need to get started in the world of gardening and grow and maintain thriving, sustainable, and environmentally responsible food gardens and landscapes.” [22]

In the same vein, agriculture is only referenced in this project as it relates to community agriculture, collective agriculture, and civic agriculture. This project does not explore the impact of home growing or sustenance farming on commercial agriculture as a whole, but rather aims to emphasize the gap in resources for small-scale food production. Horticulture, as referenced in the project, can be defined by the Michigan State University College of Agriculture and Natural Resources as the “the science and art of the development, sustainable production, marketing and use of high-value, intensively cultivated food and ornamental plants.” [23] In the context of this project, horticultural references are specific to the cultivation of edible and medicinal plants.

[22] National Gardening Association, https://garden.org/about/intro/
[23] “College of Agriculture & Natural Resources Department of Horticulture.”

Food justice and policy in NYC

The 2020 pandemic highlighted key issues in New York City's food access, exacerbating both financial and logistical issues preventing New York City residents from accessible fresh, healthy food. The "Food Czar team", an interagency collaboration between the Mayor's office of Food Policy, Department of Sanitation, Emergency Management, New York City Economic Development Corporation, Department of Transportation, Taxi and Limousine Commission, and others, developed programs to address food insecurity issues in their relation to the pandemic and future emergencies. The April 2020 Feeding New York report outlines the major tenets of the plan including a $25M investment in the City's pantry system, the establishment of a $50 million emergency food reserve, and the creation of GetFood NYC. GetFood NYC included the Department of Education (DOE) Grab & Go Meal program, the Emergency Food Home-Delivered Meal (EFD) program, and increased support and coordination for pantries and other emergency food distribution efforts. The issues identified in 2020 continue to serve as drivers for building more resilient food access and food emergency systems, through combined investments in SNAP benefits, food distribution, and healthy food education[24].

As part of this invigorated food justice investment, the city released its first 10-year Food Policy plan, Food Forward NYC[25], in 2021. Food Forward NYC lays out a comprehensive policy framework to reach a more equitable, sustainable, and healthy food system by 2031, including robust metrics in identifying the food "supply gap" with enhanced data to identify neighborhood-level unemployment rates and the presence of undocumented populations with barriers in accessing public aid. This data helps build policies and plans to address sustainable food systems, and has been incorporated into the distribution of financial food justice resources. Food Forward helps allocate and support resources across SNAP, GrowNYC, and Greenthumb initiatives.

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[24] MacKenzie, "2021 Food Metrics Report."
[25] "Food Metrics Report - Food Policy."
https://www1.nyc.gov/site/foodpolicy/reports-and-data/food-forward.page

In 2021, the city received a $5.5m grant to make healthy food more affordable, and used the funding to address financial barriers SNAP recipients may have in accessing healthy food. The funding was allocated towards supporting “Health Bucks” and “Get the Good Stuff”, two SNAP benefit matching programs implemented at Greenmarkets (NYC farmer’s markets) and traditional grocery stores, respectively. For every $1 spent in SNAP benefits on eligible fresh, frozen, canned, and dried fruits, vegetables, and beans, program participants get $1 added to a program loyalty card, to purchase more eligible foods. With a 44% increase in SNAP usage during Covid-19, increasing the purchasing power at farmers markets and other food access sites is an important investment and has helped more than 7,000 New York residents redeem more than $1.25m worth of fruit and vegetable incentives as of March 2021[26].

The 2021 Food Metrics report further details educational investments in community-led food systems, including resources and data allocated to the urban gardening program Greenthumb, GrowNYC School Gardens, the NYC Farm to School Program, and Farms at NYCHA[27].

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[26] Gallahue and Merlino, “Good Health, Good Value: NYC Receives $5.5 Million Grant to Make Healthy Food More Affordable.”

[27] MacKenzie, “2021 Food Metrics Report.”

Investment shifts in local food systems

While investment in urban agriculture and community-led food systems is not necessarily new in New York City, the pandemic-informed food policy has reprioritized investment in locally-grown, collective food access. Urban agriculture policy pushes were previously slow-moving for at least 10 years, with in-depth research detailing the potential impact of Urban agriculture in NYC as early as 2012[28]. There have been notable disconnects between park and beautification initiatives and food access initiatives. In 2007, urban forestry movements such as One Million Trees and PlaNYC saw traction in operations with no mentions of urban agriculture. Lindsay K. Campbell, a research scientist with the New York City Urban Field Station identifies a number of reasons for this in her book, “City of Forests, City of Farms”:

> “In the urban forestry case, we see mayoral commitment operationalized through a savvy municipal agency (DPR), coupled with an influential nonprofit (NYRP)...Urban forestry is centralized around the key, professionalized public agency of DPR, whereas urban agriculture is a more polycentric, civic-led network with a long history as a social movement… Limitations of space, cost, and productivity have pushed urban agriculturalists into thinking at broader scales and forming regional alliances in support of the entire food system, from production and processing to consumption and post-consumption.”[29]

Many past initiatives dedicated to passing urban agriculture-related legislation stalled due to the lack of comprehensive plans and integrated municipal resources. Kristen Reynolds, a visiting professor in the Environmental Studies and Food Studies at the New School, notes in a 2019 piece for the CUNY Urban Food Policy Institute:

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[28] Plunz et al., “Growing Capacity, Food Security, & Green Infrastructure.”
[29] Wolf, “Research Guides @ Fordham.”

"In New York, many gardeners, farmers, advocates, and, more recently, entrepreneurs argue that policies should facilitate long-term use of city land for urban agriculture, or remove barriers to entry for new businesses hoping to start-up in the Big Apple. And, as new forms of food production such as indoor hydroponics and remotely-controlled systems have joined longer standing community-run farms and gardens, an increasing number of New York City policy makers are joining in their support for such ideas. Nonetheless, to date, there is no comprehensive policy plan systematically guiding the existence of urban agriculture in the city, including its 1,200 community gardens; 490 school gardens; and 20 community farms and its growing commercial sector (cf. Reynolds and Darly 2018; Reynolds and Cohen 2016; Altman et al. 2014; Cohen et al. 2012)." [30]

Recent momentum for a comprehensive policy plan in the use of city land has been built from the collective planning and advocacy efforts of public institutions, community-led organizers, and nonprofits in the urban agriculture space. Encouraged by "The Agricultural Improvement Act of 2018" (H.R.2 115th Congress 2018)[31], NYC urban agriculture advocates attempted to pass "Requiring the dept of city planning, dept of small business services, and the dept of parks and recreation to develop urban agriculture website." (Int. 1661-2017)[32]. An amended version of Int 1661-2017 was passed in 2018, requiring the New York City Department of Small Business Services, and Department of Parks and Recreation to create an urban agriculture website. Shortly after, "A Local Law to amend the New York city charter, in relation to developing an urban agriculture report" (Int 1058-2018) was proposed, which updated the urban agriculture plan requirements deadline detailed in Int. 1661-2017 from July 2018 to July 2019. New York City's Land Use Planning committee held a hearing for Int. 1058-2018 in June 2019 where approximately two-dozen urban agriculture advocates submitted in-person and/or written testimony. Testimony at

[30] Reynolds, "Perspectives on Int. No. 1058-2018: A Local Law in Relation to Developing a Comprehensive Urban Agriculture Plan."
[31] "Summary of H.R. 2 (115th)."
[32] "The New York City Council - File #: Int 1661-2017."

the hearing expressed support for the bill with perspectives from community gardens, policy groups, and urban agriculture groups and detailed what and how the office should be created. The hearing and additional support from the Mayor's office, the nonprofit NYC Agriculture Collective[33], and food policy groups eventually resulted in the passing of Int 1058-2018 in November 2021, resulting in the following law:

> "This bill would require the Office of Urban Agriculture to prepare an urban agriculture report by October 1, 2023 and every five years thereafter in cooperation with several stakeholders including relevant agencies, food policy educators, community gardens and urban farming businesses." [34]

Since the passing of Int 1058-2018, New York City has reshaped policy to embrace "The New Agrarian Economy", with notable investment from former Brooklyn Borough President and current NYC mayor Eric Adams, stating:

[33] NYC Agriculture Collective, "NYC Agriculture Collective."
[34] "The New York City Council - File #: Int 1058-2018."

> "The COVID-19 pandemic has exposed the fragility of our city's economy and the deep inequities embedded in our food system. Urban agriculture has the potential to revolutionize our urban landscape and play a significant role in an equitable recovery process, helping us to become a greener, healthier, more prosperous city after the pandemic. Our new report lays out a roadmap for achieving that, proposing steps that build on my previous advocacy efforts in Brooklyn. As the past several years have shown, there is tremendous economic potential in this promising sector — we just need the political will to invest the necessary resources to encourage its growth." [35]

Disconnects in the research timelines between educational institutes and public initiatives can be seen in the 2012 report "The Potential for Urban Agriculture in New York City" from the Urban Design Lab at the Earth Institute at Columbia University through the 2021 report "The New Agrarian Economy" from the NYC Mayor's Office along with New York University (NYU) Stern Center for Sustainable Business and the Cornell University College of Agriculture and Life Sciences. The conclusion can be reached that the gaps found by the 2020 Food Czar team in their efforts to address food insecurity caused by the pandemic and security in the City's food supply chain, can be addressed with renewed legislation and investment aligned across urban agriculture and AgTech initiatives, as shown in the 2021 Food Metrics Report.

[35] Allon, "The New Agrarian Economy Report On Expanding Urban Agriculture In NYC."

The role of gardening in NYC Urban Agriculture initiatives

The larger picture of urban agricultural investments is attempting to incorporate the long, deep roots of the community gardening movement into the food justice policies shaped by the 2020 pandemic. This mirrors the history of community gardens in New York City, which were born of activists' efforts to address the economic issues of the 1970s through collective, engaging greenery. In 1973, a nonprofit environmental group known as The Green Guerillas began lobbing "seed bombs" made of fertilizer, moist soil, and seeds into vacant lots in an attempt to rebuild abandoned buildings and vacant lots with greenery. These efforts beautified economically depressed spaces and fostered vibrant communities, with The Green Guerilla hosting workshops and events to encourage neighborhood participation. NYC parks details in the post "History of the Community Garden Movement:

> "Realizing the wisdom of outsourcing the maintenance of vacant city–owned lots to energetic community groups willing to tend to them and wanting to encourage grassroots neighborhood revitalization efforts, the City initiated the GreenThumb program in 1978 to provide assistance and coordination. Originally sponsored by the City Department of General Services and funded by federal Housing and Urban Development Community Development Block Grants… GreenThumb coordinated the leases for city–owned vacant land. Whether through vegetable plots or lush flower or herb gardens, residents transformed unattractive and sometimes unsafe spaces into green havens, providing open space in especially underserved areas." [36]

[36] NYC Parks, "Green Guerrillas Gain Ground."

Today, GreenThumb, is the nation's largest urban gardening program, providing assistance and support to more than 550 gardens and 20,000 garden members throughout the city. Community gardens account for more than 100 acres of public open space in the city, and more than 300 of 356 visited sites produce food in 2022. The combined GreenThumb sites currently growing food in community gardens cover 274,317 total acres across at least four boroughs. [37]

Fig. 1: Community garden food production

Acreage of community gardens growing food by borough	
Borough	**Acres**
Brooklyn	227,997
Manhattan	17,234
Queens	24,809
Bronx	4,277
Total	**274,317**

Source: NYC OpenData GreenThumb Garden Info, GreenThumb Block-lot

This staggering majority of community gardens producing food in New York City may be related to the renewed investment in urban agriculture. As Campbell points out in "City of Forests, City of Farms", lacking infrastructure and resource support may be underpinned by a previous lack of "quantified metrics about the benefits of urban farming and community gardens"[38]. The researchers at the Urban Design Lab at the Earth Institute of Columbia also note that:

[37] "GreenThumb Site Visits | NYC Open Data."
[38] Campbell, *City of Forests, City of Farms*.

> "Urban farmers and gardeners will generally strive to make land under cultivation as productive as possible while ensuring long-term soil health and maintaining sensitivity to ecological constraints and the needs and preferences of the communities within which the land is located." [39]

Previous and current initiatives for New York City illuminate that policymakers are inherently motivated by bottom-line numbers and impact assessment. As data for community-driven programs improves and the cost-benefit of growing food locally becomes clearer, public initiatives are beginning to develop more rapidly to the most pressing needs of New York City Residents.

[39] Plunz et al., "Growing Capacity, Food Security, & Green Infrastructure."

Resources for gardeners

Local resources in growing plants are now provided with a number of public institutions and educational extensions in New York City, whether motivated by policies passed or research needed. The NYC Urban Agriculture website "connects (users) with opportunities to become a part of the agricultural community in the city, serving as a one-stop shop for resources, programs, and regulations that help grow agriculture in New York City" [40]. GreenThumb provides detailed instructions and support for "How to Start a Garden" [41], with increased investments over the last four years[42]. The Urban Soils Lab at Brooklyn College provides affordable soil testing services by mail and drop-off helping both home and community gardeners stay informed about their environmental resources[43].

Additional resources built outside of New York City programs can and should be widely circulated to help connect gardeners to information about growing plants successfully. The United States Department of Agriculture provides agricultural assessment tools such as the PLANTS Database[44] and the recently refreshed Plant Hardiness Zone Map[45]. The National Association of Gardeners provides a number of Learning Library resources [46] including planting calendars[47], frost date calculators[48], and materials calculators[49]. Online communities, though not as fundamental in successful plant growth as locally-specific, collective education from within communities, can aid new gardeners in self-education journeys by providing documented experiences and

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[40] "NYC Urban Agriculture." https://www1.nyc.gov/site/agriculture/index.page
[41] "Start A Garden : Get Involved : NYC Parks GreenThumb." https://greenthumb.nycgovparks.org/start_a_garden.html
[42] NYS Division of Budget, "Agency Appropriations Budget Highlights."
[43] "Urban Soils Lab at Brooklyn College." http://www.brooklyn.cuny.edu/web/academics/centers/esac/soil.php
[44] "USDA Plants Database." https://plants.sc.egov.usda.gov/home
[45] "USDA Plant Hardiness Zone Map." https://planthardiness.ars.usda.gov/
[46] "Garden Learning Library." https://garden.org/learn/
[47] "When to Plant Vegetables." https://garden.org/apps/calendar/
[48] "Frost Dates." https://garden.org/apps/frost-dates/
[49] "Gardening Calculators." https://garden.org/nga/calculators/

crowd-sourced question forums. Listings of locally specific, nationally supported, and online community tools may be found in Appendices A1 and A2 of this document.

The local growing and urban agriculture landscape is fragmented across bureaucratic, political, and economic borders, with only very recent initiatives aiming to align resources. From the Ground Up joins the ever-growing resources for gardeners by addressing individual barriers to local growing addressing some of the individual knowledge gaps surfaced in home growing initiatives. This project aims to increase urban agriculture engagement on an individual level, through the use of human-centric data design and modern data practices.

Treatment

Methodology

Understanding the landscape in which horticultural data can be found involves researching gardening communities online as well as offline. While the tool itself explores data for growing and using specific plants that can grow in a temperate climate zones[50], the infeasibility of individual growers supporting their own food needs entirely enforces the notion that community gardens, urban agriculture, and farmer's markets will continue to play large roles in accessing locally grown food. This thesis employs mixed methodology research methods in both research and proposed solutions in the design of the project that are relevant for individual as well as community-led urban agriculture initiatives. Quantitative data can be found in the measurements, spatial data, and patterns displayed in the plant data while qualitative data can be found in the environmental tests, cultivation notes, and user interface choices developed with the use cases derived from in-person conversations.

[50] US Department of Commerce, "NWS JetStream - Climate."

Offline research

This research suggests that both individual and in-person education will be needed to fill in the knowledge or investment gaps currently identified in local food initiatives. As the aim of this tool is to encourage curiosity, education and confidence in plant needs so that users feel more empowered to grow their own plants in their communities and homes, in-person research became part of the mixed methodology process. This involved talking to local garden communities to get a sense of different perspectives and aims with personal growing projects such as members of local community gardens, workers at garden shops, and everyday plant enthusiasts.

Participants expressed different priorities and values when planning out their gardens through a series of loosely structured conversational interviews. While many answers to questions about what new gardeners need to know to begin focused on light and ability to water/care for the plant, answers also included insights such as “pets”, “hazards” and details about soil quality. Further insight was found in answers to questions about how these gardeners prioritize their plant choices, ranging from aesthetic choices and variety to origins of native plants. Learnings from in-person conversations not only expanded the depth of the user journeys developed, but also explored the user experience pattern of learning why different variables in growing plants are important. Full notes from the full ten interviews conducted can be found in Appendix B of this document.

This mixed methodology research resulted in the constructed hierarchy of environmental/ecological variables allowing users to engage with the variables they understand *at present*, with the ability to expand their understanding through educational ranges and aggregated resources.

Online research

Online research for this project included aggregating a number of online communities, databases and resources to provide as clear an overview as possible, and including different kinds of media into the tool in a comprehensive way. Quantitative online research included collecting United

Nations food policy data, NYC Urban Agriculture initiatives, and GreenThumb community garden information, while quantitative research included geospatial and environmental resources from the USDA. While there are a number of databases for growing plants and their uses available online, quantitative research was found to be largely applicable to production agriculture and environmental science research.

As plant data is constantly changing to reflect new research and evolving environments, the data landscape for growing plants is at present fragmented and somewhat dated. Digital departments at government agencies have redesigned websites to be more intuitive and are working to maintain more modern technologies like APIs and open source databases, though progress moves slowly. At the time of this project, the USDA's Plants Database API had been removed after a website redesign and temporarily maintained by individuals but had not been made publicly available from the USDA itself. [51] This instance affirms the difficulty in (and demand for) modern, rich environmental datasets from verified sources. While digital systems work to keep up with best practices, plant data communities continue to be supported by individual contributors and organizations.

One such organization is Plants for a Future, a UK-based organization with in-depth plant information distributed online as well as through a series of published books. Plants for a Future is an experimental field research non-profit that has been researching, documenting, and publishing information about edible and medicinal plants since 1989. Plants for a Future has more than 5 books on food forests and edible plants published in addition to numerous ebooks, leaflets, and translated versions.[52] The Plants for a Future database most closely aligns with the ethos and aims of this thesis for its collective information sharing practices, the range of cultivation and tolerance details covered, and the thorough citation of aggregated data found in publications and databases. In recent years Plants for a Future has further worked on extending the plants database with initiatives to support "carbon farming" - farming methods which sequestrate carbon in the soil[53] -

[51] "API for USDA Plants Database?" https://github.com/USDA/USDA-APIs/issues/7
[52] Fern, "Plants for a Future." https://pfaf.org/user/AboutUs.aspx
[53] "Carbon Farming Project."

and “food forests” or “food gardens”, which contain a variety of food plants grown to emulate ecosystems and growing patterns found in nature.[54]

The Plants for a Future database drives the majority of the quantitative and qualitative content in this thesis for its ease of use, depth, and relevancy to New York growing variables. Other databases were referenced to fill in gaps in the Plants for a Future database, including information from the The National Association of Gardeners[55], the USDA Plants Database[56], and the Wordpress Openverse project[57].

Data processes

While the Plants for a Future research aligns closely with the aims of this thesis, there were still decisions and processes that required reworking in order to make the data the most useful for the intended audience. Optimizing the original SQL tables for the intended interface and audience was an instrumental data process in parsing the Plants for a Future information. Given the size of the database, reorganizing and minimizing table access was crucial in creating one cohesive JSON file to better visualize the most important relationships for beginner gardeners. Resources from the National Association of Gardeners, the USDA, and Openverse were also added to the data set to encourage users to continue their own research from a variety of sources and to provide Creative Commons images.

One of the data points requiring processing were the listed “hardiness zones”, which are defined by the average annual minimum winter temperature in a given region. Hardiness zones are the standard by which growers can determine which plants are most likely to thrive at a location[58], and incorporating them as a feature can help users make informed choices about their plants. While the

[54] Wyatt, “Establishing a Food Forest.”
[55] National Gardening Association, “Plants Database.” https://garden.org/
[56] “USDA Plants Database.” https://plants.usda.gov/
[57] “Dear Users of CC Search, Welcome to Openverse.” https://creativecommons.org/2021/12/13/dear-users-of-cc-search-welcome-to-openverse/
[58] “USDA Plant Hardiness Zone Map.”

Plants for a Future database aligns with UK hardiness zone measurements, the data team was able to provide correlations to USDA hardiness zone measurements for this project. The UK hardiness data was converted loosely to USDA hardiness measurements using the following conversions:

Fig. 2: Plants for a Future/From the Ground Up hardiness temperatures and ranges

PFAF Hardiness	PFAF Hardiness temp (F)	UK Hardiness	UK Hardiness Temp (F)	USDA Hardiness	USDA Hardiness Temp (F)	Hardiness use
< 6	< 10F	5		5a	-20 to -15	Hardy to cold
				5b	-15 to -10	
6	-10 to 10	6	-10 to 0	6a	-10 to -5	Seasonal outdoors
				6b	-5 to 0	
		7	0 to 10	7a	0 to 5	
				7b	5 to 10	
7	10 to 20	8	10 to 20	8a	10 to 15	
				8b	15 to 20	
8	20 to 30	9	20 to 30	9a	20 to 25	Grown indoors
				9b	25 to 30	
9	30+	10	40+	10a	30 to 35	

The USDA's 2012 hardiness zoning system, which is also determined by lowest average temperature, is more precise than the UK hardiness system - though both have changed by several degrees in recent decades. As hardiness levels are primarily indicators of how tolerant a plant is to cold and the USDA and UK hardiness zones are, generally speaking, getting warmer - the impreciseness of the conversion doesn't necessarily detract from the end goal of using hardiness zones as a factor in success for the users of this tool. Hardiness numbers were thus converted to "hardiness uses" for the initial user experience in an effort to minimize technical jargon presented to the user.

The Plants for a Future database also consisted of inconsistencies between the various uses, cultivation details, habitats, and pollination methods between plants. Terminology for “edible”, “medicinal” and “other” uses has been reworked within this project to provide specificity within use categories. All non-edible and non-medicinal uses were initially summarily combined into one “uses” field, and edible and medicinal uses and rating fields used inconsistently in the original dataset. With the fields “Edible uses” and “edibility rating” recorded alongside “Medicinal”, “Medicinal rating” and “Uses notes:

Fig. 3: Plants for a Future/From the Ground Up uses conversion

PFAF	FTGU	*formula*
Known Hazards	Hazards	
Edibility Rating	Edible Rating	
Edible Uses	Edible Uses	
Medicinal	Medicinal Uses	
Medicinal Rating	Medicinal Rating	
Uses notes	Material Uses	
	Material Rating	Material uses length: 0-200 = 1, 201-300 = 2, 301-400 = 3, 401-500 = 4, 500+ = 5
	Usefulness	Medicinal rating + Material rating + Edible rating * 2
	Hardiness use	Hardiness: 0-5 = "Hardy to cold", 6-8 = "Seasonal outdoors", 9-12 = "Grown indoors"

Additional terms and phrases used in the interface within From the Ground Up have been chosen to reduce the cognitive load of the users’ experience. Data and design approaches to making plant data human readable for this project involved incorporating thoughtful copy choices for technical data and connecting consistent design decisions to decrease users’ cognitive load when engaging with new terms. The full lists of terms which have been reconfigured from the Plants for a Future database to provide consistency in filters, search, and data fields with supporting research for their practical applications can be found in Appendix C1 and C2 of this document.

Design decisions

The design of this project mirrors the real-life experience of the intended user, that is, a beginner gardener, who doesn't know what they don't know, doesn't know where to look, and is curious about plants. The most important skill this user can develop on this journey is the ability to connect and combine their resources - looking to both their community and to the experiences of gardeners around them. The initial research in this project, consisting of conversations with gardeners of different backgrounds, experiences, and priorities, was incorporated to include a variety of user needs and informed much of the resulting data hierarchy and design features.

One of the main goals of this project is to provide features that educate potential growers in a clear, consistent way. In order to make a vast amount of information engaging enough to keep users interested, data needed to be surfaced at a reasonable, parseable pace. The initial Plants for a Future database provides information for 7,414 plants with upwards of 50 data points apiece and will overwhelm users as a collection of individual data points. Thus providing hierarchy, consistency, and visual cues became a key part of the findings of this thesis. By filtering the original 7,414 practical plants down to the 5,913 that have edible properties, users are already provided a more curated experience that will help them navigate food garden-specific actions. Further filtering based on users' environmental and ecological needs provides even more manageable data for them to begin growing with, providing digestible hierarchies as well as allowing users to parse a large amount of data in a more engaging way than a table. The simple structure of the app reinforces this by elevating the most important information first: users are guided to get a quick overview of the relevancy of high-level data presented as "environmental factors" in a flowchart.

Fig. 4: Environmental variable flowchart user interface

Education data points are provided to users to help them get a better understanding of the high-level terminology and application of the information they interact with, and in-depth guides and other resources are linked out to encourage users to continue their self-education. From there, users are directed to engage with plant data through a series of filters informed by those environmental factors. The filters produce results which organize individual plants in a consistent hierarchical balance of semantic and pictorial relationships that supports easier retention of patterned information across the dataset. On the "learn" page, colors are applied to the filtered plant data with two corresponding legends which never intersect: opacities of unique hues applied across the four environmental factor data points "sun", "moisture", "soil", and "pH", and a green gradient representation of "low/high edibility", and size is applied to corresponding additional uses, and otherwise not applied to the filtered data set in the filtered cluster. On the "/dig" page, representations of plants as "cards" show the plant itself, with additional data on their names, hardiness, and general growing information. These cards are also able to be filtered by users' environmental filters as well as additional ecological filters. The environmental data are shown again in the individual plant pages, linked through both the cluster nodes as well as the cards, which helps to reiterate the initial understanding of the relevant plants. These unique representations of data values allocate attention towards the most important information in users' journey to finding the *right* plants that are most likely to be successful in their environment. As Mccrudden and Rapp note in their 2017 paper "How Visual Displays Affect Cognitive Processing":

> "Selecting important information is key because attention must be directed toward this information in order for it to be processed. Simply put, if attention is not allocated toward important information, it will not be consciously processed. Similarly, if attention is allocated toward interesting but unimportant information, those contents can disrupt the coherence of the main instructional message." [59]

Initially filtering plants by their likelihood of success in the users' environment and then displaying additional important groupings such as edibility, combined usefulness and ecological variables as secondary information, helps users focus on the content that is relevant to their own success in growing plants. Usability guidelines from groups like Neilsen Norman Group[60], Adobe[61], and Invision[62] consistently recommend grouping information in a logical way to better serve the memory and success of the user. Engaging with the only filtered results on the "learn" and "dig" pages helps offload the processing of overwhelming collection numbers and instantaneously provides the more relevant collection as a more manageable subset. This process continues to reinforce the relevancy of the environmental data presented to the user at the beginning of their journey while reducing the intrinsic cognitive load of the user experience, which the Neilsen Norman Group defines as "is the effort of absorbing that new information and of keeping track of their own goals".[63]

In addition to implementing hierarchical data practices, logical informational groupings and consistent visual displays, this project also implements faceted classification systems as a means to a more usable plant data system. Susan Dumais of Microsoft Research describes the importance of faceted classification in the 2009 edition of Microsoft's Encyclopedia of Database Systems:

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[59] Mccrudden and Rapp, "How Visual Displays Affect Cognitive Processing."
[60] Neilsen, "Short-Term Memory and Web Usability."
[61] Guerra, "6 Ways to Reduce Cognitive Load for a Better UI | Adobe XD Ideas."
[62] Krug, "Cognitive Load."
[63] Whitenton, "Minimize Cognitive Load to Maximize Usability."

> "The motivation for faceted classification and search is that any single organizational structure is too limiting to accommodate access to complex domains. Multiple independent facets provide alternative ways of getting to the same information, thus supporting a wider range of end-user tasks and knowledge. The fields of faceted classification, information architecture, and data modeling provide theory and methods for identifying and organizing facets. The user interface challenge for faceted systems is in managing this added complexity, especially when working with very large and diverse information collections. Most interfaces to faceted information provide support for structured browsing (faceted navigation or browsing). In addition, some systems offer search capabilities and, more generally, tightly coupled views of the same information." [64]

Fig. 5: Optional multiselect filters

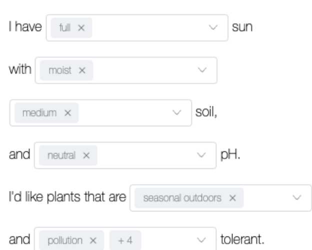
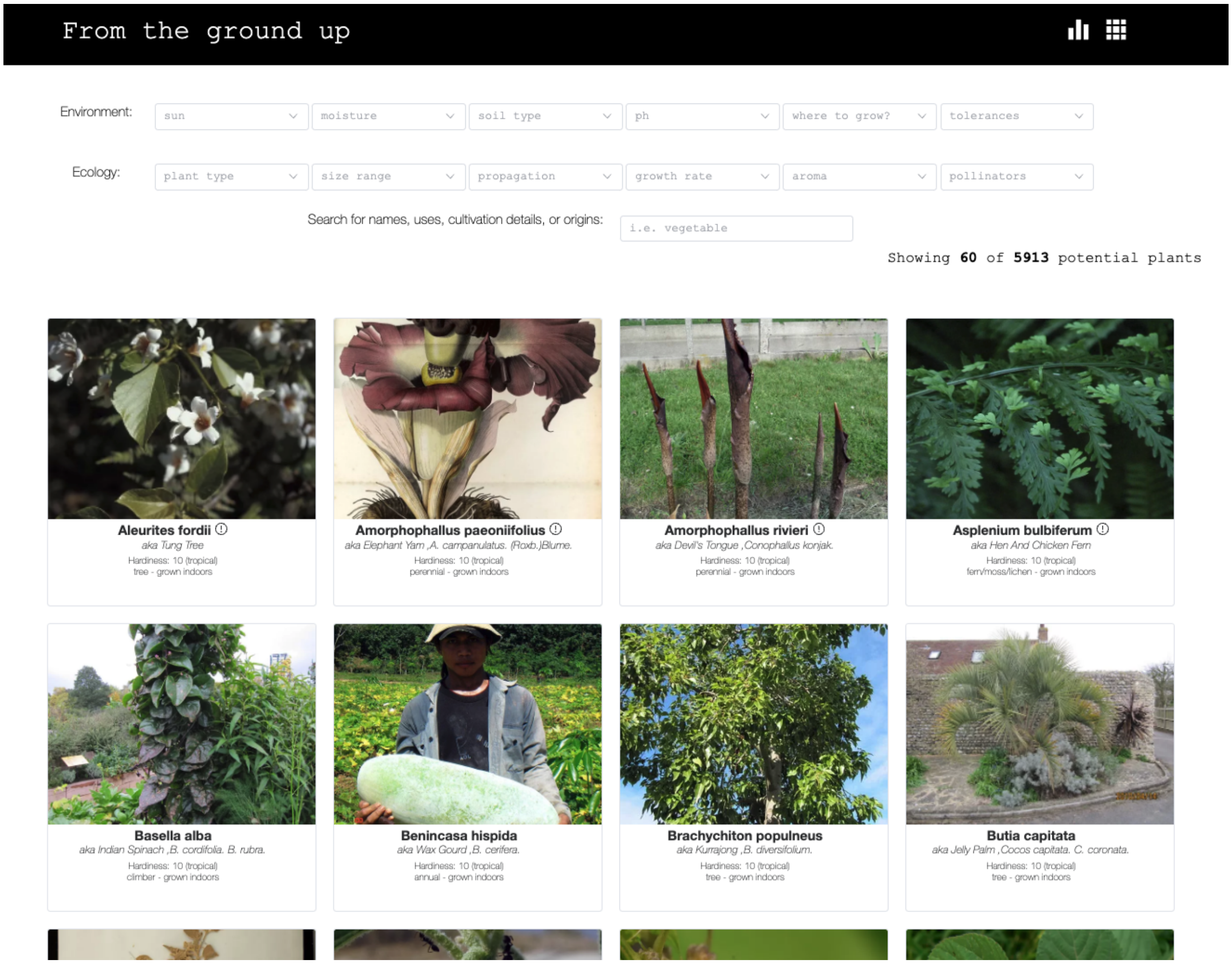


Fig. 6: Consistent, hierarchical symbolic and pictorial representations

[64] Dumais, "Faceted Search."

The ecological and environmental filters provided are entirely optional and support the selection of multiple filter choices, allowing users to dissect relevant information in an infinite number of ways to better navigate coupled information. The additional implementation of a “search” field on the “/dig” page helps users to find less-structured data across the 12 lengthy fields updated from the Plants for a Future database: latin name, common name, synonyms, tolerances, synonyms, propagation details, cultivation details, range, edible uses, medicinal uses, material uses, and indigenous use. This third, searchable grouping of highly dense information is provided to the user as a recognizable interface pattern without overwhelming users with all of the organizational work it presents. These data points are also surfaced in the individual plant pages, as individual data points within a final stop on the data journey. Thus all plant data will eventually be surfaced to the user, via the filtered clusters on the “/learn” page, through the filtered cards on the “/dig” page, or through individual plant cards, but the most interesting and important information to the user is surfaced first.

Fig. 7: Tiered filtered and search field



The final way in which this project addresses the primary aim of encouraging success in personal growing initiatives, is through the ability to save and share the plant data in modern ways. From the Ground Up allows users to process large amounts of plant data in new ways, such as allowing users to analyze clusters of plants grouped by plants that are likely to be successful in their environment, and drill down and save PDFs with rich plant data. Saving and sharing data that is relevant to a users' specific experience will encourage in-person conversations, practical applications and continued reference for self-education.

Conclusions and future research

From the Ground Up implements many modern data practices within the aggregated plant resources available, though many more have potential to expand on the usefulness of the tool. Immediate updates to future research should incorporate additional faceted information interactions such as:

- Visually augmenting tolerance and pollinator variables on the "/learn" page
- Providing hardiness and edibility sorts on the "/dig" page
- Elevating native plant through the use of icons on plant nodes, cards and pages
- Increasing visual patterns across families, uses, categorical groups, and propagation and cultivation practices

Spatial data could also be implemented with more detail to help gardeners plan quantities of plants based on the size of the plant (currently grouped as "small/medium/large", though specific average sizes of plants are stored in meters tall/meters wide. Connecting resources within From the Ground Up and the success/challenges presented to local farming could be further be used to extend the reach of public resources. For example, analytics collected from users' environmental data could provide data needed to allocate funds for subsidies for gardens and resources for soil rehabilitation, irrigation systems and testing kits. There is an ever-growing landscape of technological advancements in the field of urban and civic agriculture, and future data collected from users of From the Ground Up could also be used to implement soft clustering of plant uses, predictive plant success in specific neighborhoods, and cohabitating crop planning.

There are also a number of data and design methods that could be implemented to connect From the Ground Up resources to existing plant resources such as an interactive map page to point users to the active community gardens near them, and aggregating educational events in the New York City area from Greenthumb, GrowNYC, and other organizations. While the scope of this thesis may expand which data are presented to users and in which ways, the aim will always be to connect gardeners to their communities, which will require future work to remain up-to-date on new policies and resources available within New York City.

Appendix

Appendix A1: Key Reports and Datasets

Resource	Organization	Type	Date
Food Metrics Report	NYC Food Policy	Report	2021
New Agrarian Economy	Brooklyn Borough President	Report	2021
The Potential for Urban Agriculture in NYC	Urban Design Lab at the Earth Institute Columbia University	Report	2012
City-owned sites that are available and potentially suitable for urban agriculture	NYC OpenData	Dataset	2021
GreenThumb Site Visits	NYC OpenData	Dataset	2022
GreenThumb Garden Info	NYC OpenData	Dataset	2022
Plants for a Future	Plants for a Future	Database	2022
The Ferns	Plants for a Future	Database	2022
Plant Databases	National Gardening Association	Database	2022
Practical Plants Wiki	Practical Plants	Database	2022
Edible Plants of the World	Food Plants International	Database	2022

Appendix A2: Relevant Resources and Communities

Resource	Organization	Type	Date
GrowNYC	New York City Parks	Hub	2022
Greenthumb	New York City Parks	Hub	2022
NYC Urban Agriculture	New York City	Hub	2022
NYC Ag Collective	NYc Agriculture Collective	Hub	2022
Gardening with New York City Native Plants	Natural Areas Conservancy	Guide	2022
Garden question database	National Gardening Association	Community	2022
Growstuff	Opensource	Community	2022
Openfarm	Opensource	Community	2021

Appendix B: Garden specialist interviews

Name	Location	Level	Date	What is the most important factor to you when beginning to grow?	Considerations for new gardeners	Where do you look for information for growing?	Why do you choose what you choose to grow?	Notes
Alex	New Orleans	Beginner	3/16/22	Native planting, companion planting	Consider how this plant will interact with the rest of the ecosystem. Look up mycorrihizae networks.	Online?	Allergies,soil fixers, etc.	
Renaldo	Natty Garden	Intermediate	3/17/2022	Soil, light, resiliance	Ask them if it's their first plant, how much attention they can give it, whether they have any pets.	Ask another gardener (Toya)	I think about how it will improve my life	Music for plants!
Christina	Roots	Intermediate	3/18/2022	Light, aesthetic	Light	Ask Deborah, plant apps, internet ("never do")	How it looks and grows (colors, climbers, etc.)	
Steven	Roots	Intermediate	3/18/2022	Soil needs	Get soil tested	Food co-op, friends	Variety, resistant to preydators	
Deborah	Roots	Expert	3/18/2022	Light and space	Fertilizers, tests, water compost	N/A	Balance, food	
Brian	Cityscapes	Expert	3/22/2022	Soil condions - ammend it,condition, not soil, peat, etc. What I would do to the bed itself - how I would frame the bed and plan it out. Then decide what you want to eat.	Consider placement incompatiblity i.e. sun vs. shade, etc. alkaline, etc. Urban evironments - consider soil conditions and a raised bed. Mix soil with peat and use	Extension agency from most colleges	Decide what you want to eat! Decide how much watering you want to do and what kind of soil you need	Soluble nitrogen, phosphorous levels not availble for the plants.
Charlene	Halsey Community Garden	Intermediate	3/27/2022	Sun if you're outside and light if you're inside, rotation for soil	How much can you care for it? How often can you water.	Youtube	Pick what you want to eat!	Indoor/outdoor rotation
Nicole	Umoja Learning Garden	Intermediate	4/9/2022	Soil health and contents	Heavy metals, rainwater, whatwill help fix the soil	Lotsof very nedry books! Other people, especially older gardeners	Asking other gardeners	Noted that shade might be more important for outdoor planning
Delisa	Umoja Learning Garden	Intermediate	4/9/2022	Light	What works together	Picture this app, other people	What I have - what other people are growing/recommend	"don't know how I would have done it without the community"
Angie	Good Life Garden/BK Rot	Beginner	4/9/2022	Light, where other things can grow	How much time and space	Mother		Works for BK rot

Appendix C1: Plants for a Future > From the Ground Up Schema

Original PFAF	PFAF SQL	FTGU
Latin name	Family	family
Family	Latinname	latinname
Common name	Commonname	commonname
Habit	Synonyms	synonyms
Deciduous/Evergreen	Range	range
Height	Habit	PFAFtype
Width	Deciduous/Evergreen	type
UK Hardiness	Height	timeframe
Medicinal	Width	leaftypemarker
Range	Hardyness	leaftype
Habitat	Habitat	height
Soil	Growthrate	width
Shade	Inleaf	size
Moisture	Floweringtime	PFAFhardiness
Well-drained	Seedripens	hardinessmap
Nitrogen fixer	Propagation1	hardinessuse
pH	Pollinators	habitat
Acid	FlowerType	PFAFgrowth
Alkaline	Scented	growth
Saline	Cultivationdetails	leaftime
Wind	Woodland	leafstart
Growth rate	Meadow	leafend
Pollution	Soil	flowertime
Poor soil	Shade	flowerstart
Drought	Moisture	flowerstartmonth
Wildlife	pH	flowerend

Pollinators	Acid	flowerendmonth
Self-fertile	Alkaline	seedtime
Known hazards	Saline	seedstart
Synonyms	Wind	seedstartmonth
Cultivation details	Pollution	seedend
Edible uses	Poorsoil	seedendmonth
Uses notes	Heavyclay	propagation
Propagation	Drought	proptype
Heavy clay	FrostTender	propdetails
EdibilityRating	Self-fertile	cultivationdetails
FrostTender	Nitrogenfixer	pollinators
Scented	Wildlife	flowertypemarker
MedicinalRating	Usesnotes	flowertype
Author	Edibleuses	scented
	EdibilityRating	aromatic
	Medicinal	woodland
	MedicinalRating	meadow
	Knownhazards	shadeMarker
	Latinname:1	shade
	ETHRange	sun
		soilMarker
		soil
		moistureMarker
		moisture
		phmarker
		ph
		acid
		alkaline
		saline
		windmarker

		wind
		pollutionmarker
		pollution
		poorsoil
		heavyclay
		drought
		frosttendermarker
		frosttender
		selffertilemarker
		selffertile
		nitrogenfixer
		wildlife
		usefulness
		materialuses
		materialrating
		edibleuses
		edibilityrating
		medicinal
		medicinalrating
		indigenoususe
		knownhazards
		latinID
		imgthb
		imglink
		imgcreator
		usda
		usdalink
		pfaflink
		wikispecieslink
		openverselink

Appendix C2: Terminology conversions

Field	Data	Conversion
Type		
	fern	fern/moss/lichen
	lichen	fern/moss/lichen
	moss	fern/moss/lichen
	bulb	bulb/corm
	corm	bulb/corm
	grass	grass/bamboo
	bamboo	grass/bamboo
	perennial climber	climber
	annual climber	climber
Pollinators		
	lepidoptera	butterflies/moths
	butterflies	butterflies/moths
	moths	butterflies/moths
	cleistogamy	asexual/self
	cleistogamous	asexual/self
	cleistogomous	asexual/self
	cleistogomy	asexual/self
	apomixis	asexual/self
	apomixy	asexual/self
	apomictic	asexual/self
	self	asexual/self
	dryoptera	asexual/self
	midges	insects
	hoverflies	insects
	diptera	insects
	hymenoptera	insects
	flies	insects

	beetles	insects
	wasps	bees
	bumblebees	bees
Propagation		
	stratified seed	pretreated seed
	scarify seed	pretreated seed
	cold frame	pretreated seed
	pre-soak	pretreated seed
Tolerances		
	frosttender	FALSE

Latin name	Data notes
Begonia palmata	Hardiness estimated
Brasenia schreberi	Hardiness estimated, synonym added
Canarium album	Hardiness estimated, Habitat updated, Height updated
Cibotium barometz	Updated propagation details from https://tropical.theferns.info/viewtropical.php?id=Cibotium+barometz
Comandra pallida	Hardiness estimated
Cytinus hypocistus	Hardiness estimated
Eichhornia crassipes	Hardiness estimated
Elytrigia repens	Moved rhizomes to prop details
Gunnera perpensa	Hardiness estimated
Justicia procumbens	Hardiness estimated
Lemna minor	Added "M" soil marker as it can sometimes attach to soil in shallow puddles
Melastoma dodecandrum	Hardiness estimated
Orobanche ammophyla	Hardiness estimated
Orobanche ludoviciana	Hardiness estimated, Common name edited from "Broom rape"
Orobanche uniflora	Hardiness estimated, Common name added
Poliomintha incana	Added propagation details from https://plants.usda.gov/home/classification/46294
Potamogeton crispus	Hardiness estimated
Potamogeton natans	Hardiness estimated
Pyrularia edulis	Hardiness estimated
Scaevola spinescens	Hardiness estimated, Height added
Selaginella tamariscina	Hardiness estimated
Zostera marina	Hardiness estimated

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